

HEART RATE PATTERNS OBSERVED IN MEDICAL MONITORING

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INTRODUCTION This paper presents a classification and examples of heart rate patterns observed in response to a variety of stresses encountered in aerospace flight. The pattern classification provides a basis for automated quantification of heart rate responses. Conditions under which these patterns have been observed include sleep, quiet resting awake, clinical dynamic stress testing, and aircraft flight.

Two instrumentation requirements were met to observe these patterns. First, electronic analysis of heart rate (cardiotachometry) was applied to electrocardiograms obtained continuously. Secondly, the output of this cardiotachometer was recorded at a low paper speed of approximately 1 millimeter per second.

INSTRUMENTATION FOR MEASURING HEART RATE Electrode selection, placement, and the electronics associated with tachometry has been specifically oriented toward obtaining noise free heart rate records. The electrodes ⁽¹⁾ were applied using a variety of adhesives.

When the primary purpose for recording ECG (electrocardiogram) is to determine heart rate, two electrode location factors are important. First, the electrode location which gives the maximum QRS amplitude compared to P wave and T wave amplitude is desirable. Second, an electrode location which provides an ECG free of EMG (electromyogram) artifact is desirable. Since wave form interpretation is not a primary objective, nonstandard lead locations are acceptable. The first consideration, maximum QRS amplitude compared to other ECG components, can often be reasonably well satisfied with one of the three standard limb leads. One of the most consistently reliable electrode locations places one electrode on the midsternum and the other near the apex beat in the region of the mid-clavicular line over the 5th rib. The second consideration, minimum physiological noise, is rarely met by either the standard limb leads or vectorcardiographic (X, Y, Z axis) leads. Generally, the most artifact-free ECG is obtained by placing the active electrodes over the upper and lower portions of the sternum. In many subjects, this compromises the first consideration especially during stress testing. This is especially true if the subject has a strongly horizontal QRS loop vectorcardiographically. Many times the best compromise must be determined on each individual by testing various electrode placements prior to dynamic stress testing.

The electronic detection and measurement of heart rate involves two primary functions: recognition of a cardiac cycle, and measurement of the period of each cycle. The latter can be

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accomplished by a number of means; there are numerous commercial instruments available to do this. The former is also relatively simple when there is a noise-free signal. This frequently is not the case in data obtained under dynamic stress and flight conditions. One of the simplest and generally most effective methods for selecting the QRS component of the ECG is the use of a band-pass filter which permits only the frequencies between 10 and 30 cycles per second to pass. The cardiometer output is recorded at a paper speed close to 1 mm/sec. (2.5"/min.).

CLASSIFICATIONS OF HEART RATE PATTERNS Most of the examples presented were selected from a series of more than 100 subjects on whom continuous respiration and heart rate records were obtained during clinical combined stress testing. This classification (2) of heart rate patterns into base rate and reflex activity has been developed to facilitate the identification and measurement of the adaptive responses of an individual to changes in his external environment or to changes in his internal state. The base value is the heart rate feature which reflects an equilibrium value produced by homostatic mechanisms acting in response to a particular state of the individual. For convenience in the automation of measurement, the value obtained by summing the number of heart beats through a minute are usually considered base heart rate values.

Reflex heart rate changes are the transient changes of heart rate which characteristically return within a few seconds to previous base values or establish a new base heart rate value. The classification outline follows:

Base Heart Rate

1. Increase
2. Decrease

Heart Rate Reflex Activity

1. Slow waves
 - a. relationships
 - (1) spontaneous
 - (2) associated
 - b. Configuration
 - (1) cardio-accelerator
 - (2) balanced
 - (3) cardio-decelerator
2. Respiration coupled heart rate activity

Figure 1 shows an example of an increase in base heart rate observed during hyperventilation which can be identified by the increased depth and frequency of inspiration. Hyperventilation is followed by 100 seconds of breath-holding. Within 15 seconds after initiation of breath-hold base heart rate has returned to prehyperventilation levels. Figure 2 shows a decrease in base heart rate of 25 beats per minute following hypoxia produced by breathing 10% O₂ for 20 minutes (Levy Hypoxia test).

Two types of heart rate reflex activity are identified: slow waves (3) and respiratory coupled heart rate reflex activity (the well known sinus arrhythmia).

Slow waves: During breath-holding a cyclic heart rate activity pattern is observed (fig. 3) which is unrelated to respiration. The natural period of this slow wave heart rate activity closely approximates 10 seconds in most individuals. This corresponds to 6 cycles per minute.

Two types of slow wave patterns are recognized depending upon their relation to respiratory activity. The first is called spontaneous slow wave activity (fig. 4) which is independent of

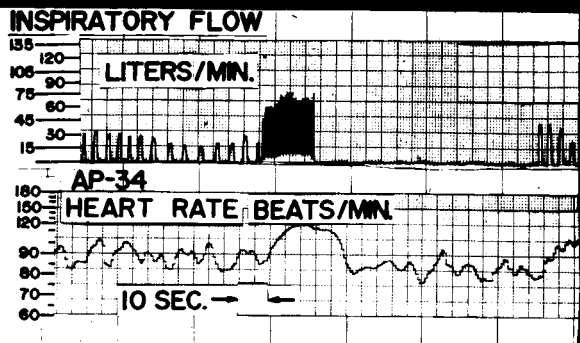


FIGURE 1



FIGURE 5

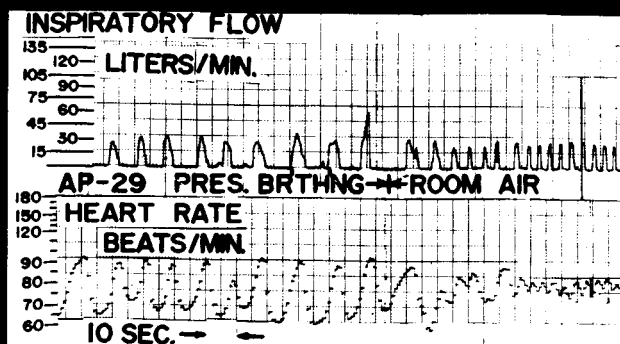


FIGURE 6

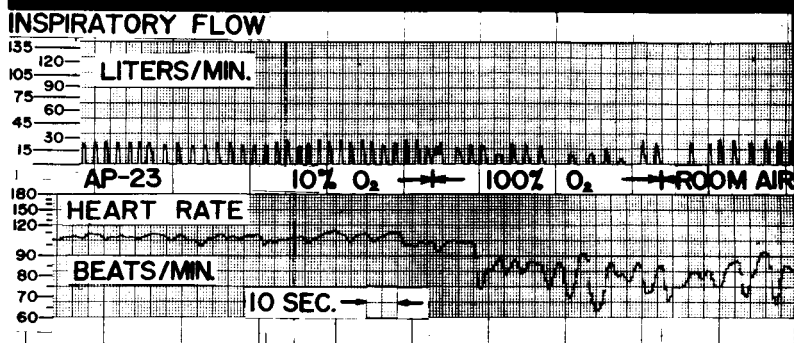


FIGURE 2

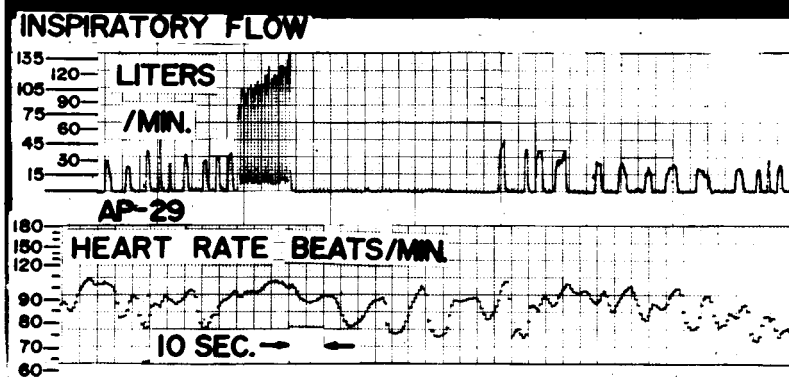


FIGURE 3

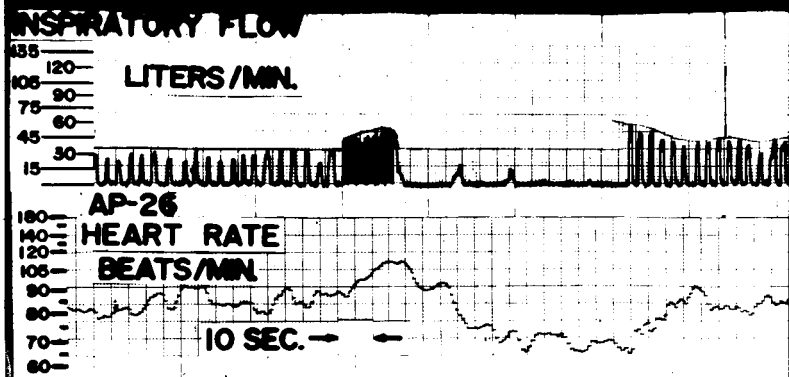
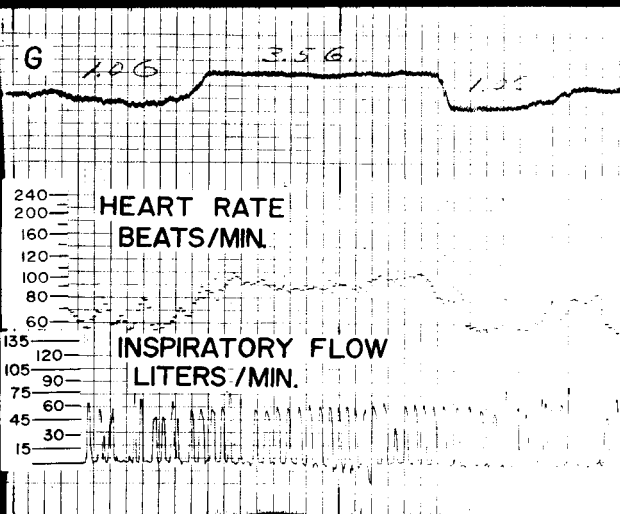


FIGURE 4



FIGURE 7



respiration and may be seen in the absence of, or during regular even respiration. Slow waves are sharply distinguished from heart rate reflex activity synchronized with the respiration cycle. Observe the similarity of the 10 second slow waves (fig. 4) during breath-holding with the heart rate reflex activity during the preceding 100 seconds. There is little evidence of heart rate fluctuations synchronized to the respiratory cycle. A second type, associated slow waves, is associated with a reflex disturbance of the respiration pattern: Either an apneustic respiration or a respiratory block (absence of one or more respiration cycles).

Either of these two types of slow wave activity may take one of three forms. Illustrations so far have presented the balanced configuration. The cardioaccelerator configuration of a slow wave is most likely to be observed during periods of low base heart rate (fig. 7) while the cardio-decelerator configuration is most likely to occur during periods of high base heart, (fig. 5). The slow wave pattern in each case characteristically begins with an increase in heart rate and terminates with a decrease. The form appears to depend upon the relative amplitude of each half cycle.

The second type of heart rate reflex activity is characterized by respiration coupling. Generally, at low respiration rates approaching 6 per minute (the slow wave natural frequency) the amplitude of respiration coupled heart rate reflex activity approaches a maximum ⁽⁴⁾. Through the first two thirds of Figure 6, the subject was pressure breathing at a rate close to 6 per minute. For the last 30 seconds of the record, he was breathing regularly at 18 respirations per minute for 30 seconds. The amplitude of the corresponding heart rate reflex activity dropped from 30 beats per minute to 6 beats per minute. This same response is also characteristically seen with slow respiration rates in the absence of pressure breathing.

STRESS RESPONSE PATTERNS Sleep records (fig. 7) generally show simple respiratory coupling of heart rate reflex activity interrupted by occasional cardio-accelerator reflexes.

During quiet resting baseline periods, the heart rate reflex activity patterns observable in a large group of individuals varies through most of the spectrum of reflex activity, frequently showing a mixture of respiration coupling and spontaneous slow wave activity.

Figure 2 shows recovery from the increased base heart rate and attenuated heart rate reflex activity typically produced by the Levy Hypoxia test.

Figure 1 shows the typical heart rate response to hyperventilation. Response to breath-holding is variable. Base heart rate may increase or decrease. Many individuals develop slow waves during the course of this test, others do not.

Exposure to increased g forces in an F100 aircraft (fig. 8) normally involves rapid onset with sustained exposure to peak g for 30 to 60 seconds. Above 3 to 3.5 g base heart rates characteristically increase to a plateau value shortly after peak g is reached, and maintain this steady value until release of g.

REFERENCES:

1. Simons, D. G. "Use of Personalized Radio Telemetry Techniques for Physiological Monitoring in Aerospace Flight", Journal of the Mississippi State Medical Association, Vol. III No. 9, Pages 413-420, Sept. 1962.

2. Simons, D. G. "Animals in high altitudes: in space capsules", Chapter 57, Pages 877-892, Handbook of Physiology - Section 4: Adaptation to the Environment, American Physiological Society, 1964.
3. Lewis, Thomas "The Mechanism and Graphic Registration of the Heart Beat" Page 369, Paul B. Hoeber, 1920.
4. Mechelke, Von Kurt "Über Die Atemschwankungen Des Blutdrucks Und Der Pulsfrequenz Beim Menschen, Pages 204-220, Archiv für Kreislaufforschung, Band 19, Heft 4-7, Mai 1953.